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MECHANISM OF THE INTERACTION BETWEEN QUARTZ GLASSES AND THE LUBRICANT-COOLANT IN GRINDING

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The mechanism of the reaction between metacide, which is a coolant-lubricant component, and quartz glass in the course of grinding is investigated. It is shown that in the absence of grinding, the main type of reaction between metacide and glass is formation of hydrogen bonds. Under the effect of mechanical action both the polymer and the glass surface are modified, and as a consequence, other types of reactions occur between glass and metacide.

Glass grinding is a complicated process that includes different chemical, mechanical, and mechanochemical interactions [1]. An important factor that determines both the grinding rate and the polished glass quality is the reaction between the components of the lubricant-coolant (LC) and the glass. The lubricant-coolant, as a rule, is an aqueous or alcohol solution of a surfactant and has a triple role: lubricant, coolant, and surfactant that decreases the work of dispersion of the treated surface.

Recently, amine-containing compounds have been introduced as surfactants, along with traditional agents [2]. These compounds include metacide (polyhexamethylene-guanidine hydrochloride), used as a component of grinding-polishing liquids for glass and as a grinding-wheel impregnator. Used as a lubricant-coolant, metacide (MC) improves the treated-glass quality and substantially increases the speed of grinding. However, the mechanism of that chemical transformations, which could account for the effect of MC in the grinding process, has not been investigated. And yet it is evident that a systematic description of such studies is necessary both for selecting an LC in each specific case and for developing scientific principles for creating new highly efficient LC components and polishing mixtures.

The purpose of the present paper is to study the reaction mechanism at the phase boundary of the LC solution (metacide) and the solid body (glass) using the infrared-spectroscopy method. The study was performed on quartz glass and float glass with modifying additives of the following composition (%): 73.00 SiO_2, 13.00 Na_2O, 0.25 K_2O, 3.50 MgO, 8.50 CaO, 0.10 Fe_2O_3, 1.00 As_2O_3, 0.40 SO_3.

Spectra were recorded employing the following instruments: a Perkin-Elmer-1720 IR-Fourier spectrometer, a Lambda-9 spectrometer, and a Perkin-Elmer-983 infrared spectrometer. Diffuse and mirror reflection units (Perkin-Elmer) were used to record glass surface spectra.

Two series of experiments were performed to clarify the role of chemical and mechanochemical factors: the reaction of MC with glass was investigated under mechanical treatment and without this treatment. The glasses were polished on a surface-finish grinder. A suspension of corundum particles of size 4 μm in an aqueous or alcohol solution of the LC was introduced into the zone of friction between iron and glass or glass and glass. Slime formed in the course of grinding, and this slime included the lubricant-dispersion medium, the products of the reaction between the individual components of the medium and the glass, and the lap material. The slime was poured into a test tube for sedimentary separation of the main fractions. After holding in the test tube for 1 – 2 weeks, two clearly expressed layers formed. The upper layer was a low-viscosity semitransparent liquid (analysis proved it to consist mostly of waste MC), and the lower layer was a highly concentrated dispersion of solid particles of the abrasive and particles of glass wear.

Adsorption (the reaction of MC with glass without grinding) was carried out by placing the glass in an aqueous solution of the LC for the time needed to establish adsorption equilibrium. This time was determined beforehand by weighing the glass, dried to a constant weight, with the LC adsorbed on its surface.

The IR spectra of both series were compared with the spectra of the initial MC and glass.

Analysis of the results obtained showed that the main reaction of MC with quartz glass both under mechanical treatment and without it is the formation of hydrogen bonds between surface hydroxyl groups in the glass and N – H groups in MC. The spectra support this in the following way: the in-

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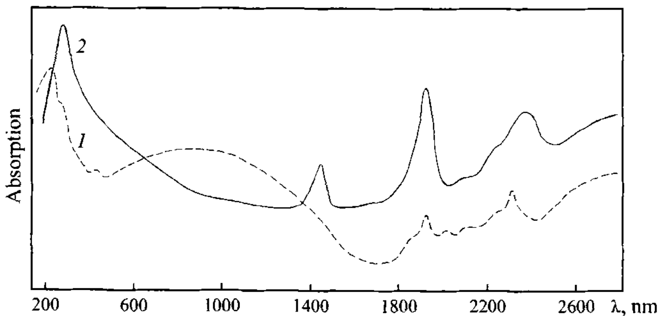

Fig. 1. Diffuse-reflection spectra of quartz glass (*1*) and float glass (*2*) in the region of 280 – 2600 nm.

tensity is increased and a low-frequencyshift in the absorption in the range of 3200 – 3450 cm^{-1} (stretching vibrations of NH and OH groups) and a high-frequency shift in the absorption in the range of 1600 – 1650 cm^{-1} (deformation vibrations of the same groups) occur [3].

However, certain differences were observed in the spectra of the two series, which were difficult to identify. This is due to the fact that the reaction of the LC with glass is represented mostly by O – H and N – H groups, which absorb in the region of 3200 – 3400 cm^{-1}, and therefore, very wide and poorly resolved bands are present in the spectra. For correct interpretation, absorption and diffuse-reflection spectra were measured in the near IR region, in which composite frequencies or overtones are manifested and the bands are separated from each other. It was found (Fig. 1) that the IR spectra of glasses subjected to mechanical treatment with the LC exhibit absorption bands at 2050 – 2400 nm that are related to combined frequencies of N – H groups [4]. At the same time, the spectra of glass in contact with an aqueous solution of MC without mechanical treatment do not contain these bands.

In order to account for the results obtained, it is expedient to perform a similar study on MC that participated in mechanochemical interaction.

The composition of the LC is constantly changed in the course of grinding, since the LC accumulates products of the mechanochemical reaction, which affect the process, and therefore, it seemed necessary to analyze the change in the MC composition with time. The reaction products of MC and the glass were isolated by sedimentary separation and subsequent centrifuging.

Successive analysis of the spectra of the initial MC and MC that participated in the mechanochemical process for various times indicated a change in the MC structure. Thus, the additional absorption at 1000 – 1100, 1250, and 1420 cm^{-1} observed in the IR spectra of samples subjected to grinding for over 1 h is probably due to incorporation of siloxane groups in the MC structure [5]. This conclusion is based on the simultaneous appearance of these bands in the spectra of samples ground for more than 1 h. Moreover, additional absorption appears at 2962 cm^{-1} in the region of

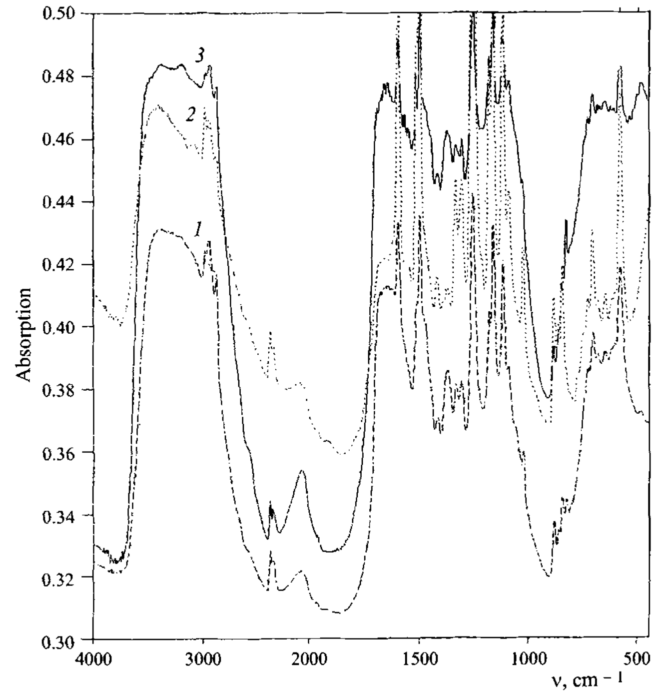

Fig. 2. IR spectra of metacide that participated in grinding for 1 h (*1*), 2 h (*2*), and 3 h (*3*).

stretching vibrations of C – H groups (Fig. 2). The appearance of this absorption band, related to end CH_3 groups, indicated destruction of MC [6].

As the grinding duration was increased, the intensity of this band decreased, and after 3 h it disappeared from the spectrum. At the same time the intensity of the absorption band at 1250 cm^{-1}, related to vibrations of Si – CH_3 groups, decreased. It is known [5] that this absorption (1250 cm^{-1}) is very sensitive to the chain length, namely, its intensity decreases as the length of the molecule increases. Moreover, with increasing grinding duration, other bands related to the polymer containing siloxane groups disappearl. After 3 h of mechanical treatment (except for slight changes in the region of deformation and valent vibrations of nitrogen-containing groups) the MC spectrum becomes similar to the initial spectrum.

In grinding for less than 1 h, no changes were recorded in the spectrum of MC that participated in the grinding process. In grinding for 2 – 3 h, additional absorption bands at 1100, 1250, and 1420 cm^{-1} and increased intensity of the band at 2962 cm^{-1} were observed. Grinding for 3 h or more brought about changes in the relative intensity of the absorption bands at 830 – 870, 1400 – 1430, 1600 – 1640, and 3050 – 3100 cm^{-1}.

Based on an analysis of the data obtained, one can make an assumption on the mechanism of the reaction between the LC and the glass in grinding. The polymer is destroyed in the first stage, and the emerging radicals initiate polymerization of $Si(OH)_4$ fragments. In the second stage (after 2 h of mechanical treatment), oligomers are formed that simulta-

neously contain amine groups and siloxane fragments. Such substances, as a rule, are instable [5] and capable of active hydrolysis. The hydrolysis products can be various ammonium derivatives capable of forming strong surface compounds with surface centers freshly formed as a result of mechanical treatment.

Consequently, the high efficiency of metacide in glass grinding is determined not only by the Rebinder effect, a necessary condition for which is the capacity of MC for strong adsorption on the surface of these glasses [7, 8], but also by other effects. At least two directions of the reaction of MC with the glass components and in a grinding liquid in mechanical treatment foster increased grinding efficiency. First, the glass surface is aminated, which impedes reverse sedimentation of $Si(OH)_4$ fragments. Second, the separated hydrocarbon radical initiates polymerization of $Si(OH)_4$ fragments. Such fragments incorporated in the metacide structure can no longer participate in the reverse reaction of polymerization of siloxane groups on the glass surface.

The results obtained suggest the expediency of using amine-containing compounds as components of grinding mixtures to improve the polishing efficiency and the product quality.

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